Monitoring for Mercury and Lead in Blueberry Plants (*Vaccinium myrtilloides* (Michx)) of the Flin Flon Area, 1980 and 1981

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ABSTRACT

Blueberry plant components and soils were sampled in 1980 and 1981 at eleven sites within the northeast and southeast quadrants, and at distances ranging from 2.0 to 40 km from the Hudson Bay Mining and Smelting complex in Flon Flon, Manitoba, Canada. Samples of unwashed and washed berries, leaves, stems, roots and surface organic layer of soil (LFH) were analyzed for total mercury and lead.

Mercury and lead levels were elevated in plant parts, but highest concentrations occurred in the LFH. Concentrations were in excess of background at sites within 19.6 km of the smelter for both quadrants.

Amounts of mercury and lead in plant parts and LFH decreased exponentially with distance from the smelter, implicating smelter emissions as the source of metal deposition.

Mercury concentrations did not exceed 0.05 µg/g, the maximum acceptable dietary concentration of mercury as published by the Food and Nutrition Board of the National Research Council of Canada.

The Concentration of lead in unwashed leaves in the southeast quadrant (primary pollutant dispersal area) ranged from 1.50 µg/g to a background level of 0.29 µg/g in 1980. Washing the berries resulted in a decrease in lead concentration, however levels found at close-in-sites still exceeded background values.

Lead levels in blueberries at sites within 5 km of the HBM&S smelter were 20 to 30 times higher than the average Canadian level of lead in berries (0.05 µg/g).

Overall, the data illustrates that site specific monitoring of vegetation and soil in primary deposition quadrants is an effective means by which to determine deposition patterns of smelter emissions in the Flin Flon area.

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I INTRODUCTION

In July, 1979 the Canadian Wildlife Service, Northern Forest Research Center, Edmonton, informed the Environmental Management Division (EMD) that elevated mercury (Hg) and lead (Pb) levels were found in blueberries (Vaccinium myrtilloides Michx) collected from the Louis Lake area, 2.5 km southeast of Flin Flon. A decision was subsequently made to conduct a research survey in August 1979 to investigate levels of Hg and Pb in blueberries and the surface organic layer of the soil (LFH). Results of that survey are contained in a report prepared by Wotton (1979). The available information was reviewed by the Manitoba Health Department and additional monitoring was recommended. Subsequent sampling of blueberries, leaves, stems, roots and LFH took place between 1980 and 1982.

This present status report will outline the surveys conducted and provide an assessment of the data collected in the course of the 1980 and 1981 sampling programs.

II METHODS

1. Sample Site Selection

The selection of sample sites was made in consideration of:

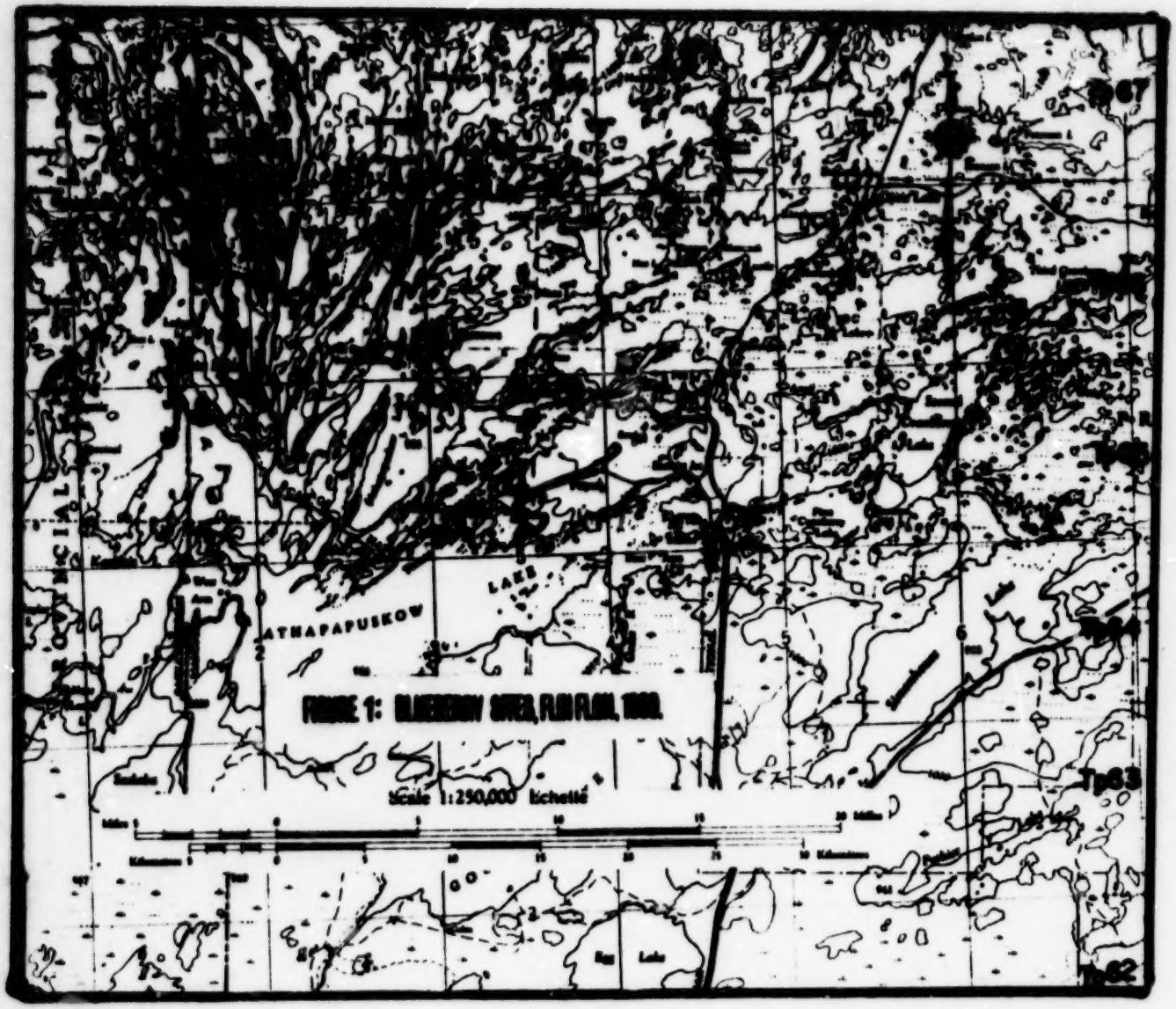
i) areas of primary pollutant dispersal

ii) areas close to the townsite and readily accessible to local berry pickers.

Eleven sites were located in the northeast and southeast quadrants to a distance of 40 km from the Hudson Bay Mining & Smelting complex (Figure 1). Site 4, 38.9 km southeast of the smelter was designated as the control site to document background levels.

2. Sampling Procedure

Samples were collected at the end of each growing season when blueberries were fully developed and ripened. Each plant was segregated into components (berries, leaves, stems and roots), placed in pre-labelled paper bags and frozen. A sample of the surface organic layer of soil (LFH) was also collected at each site. All samples were submitted to the Technical Services Laboratory, HBD, in Winnipeg for analysis.


LAKE
ATHAPAPUSKOW
Scale 1:250,000 kilometres

3. Analytical Procedure

Each plant and soil sample was analyzed for total mercury content by the Cold Vapor Technique and for total lead content by Atomic Absorption Spectrometry. Berry samples were analyzed in the unwashed (as picked) and washed conditions. This enabled us to assess whether Hg and Pb residues were restricted to surface deposition, or were incorporated into the berry tissue.

III RESULTS AND DISCUSSION

The following sections will highlight the data collected from 1980 and 1981 since the 1982 samples have not been analyzed to date.

Analytical data for Hg and Pb concentrations in berries are presented on the basis of both wet weight, that, is as eaten (Tables 1 & 2), and dry weight (Appendices A-1 & A-2). To enable direct data comparison, wet weight figures were standardized to a 70 percent water content; the 70 percent is based on mean water loss data. The following formula was used to convert the dry weight concentration to standardized wet weight values:

$$W = D(0.30)$$

where

D = dry weight concentration
0.30 = constant based on the fraction of dry material in the total rehydrated weight i.e. 1.0-0.70
W = adjusted wet weight concentration

1. Mercury Analysis

The 1980 and 1981 mercury concentrations in blueberry plant components and LFH are presented in Table 1 and Figures 2-5. Mercury data for blueberry fruit, leaves, stems, roots and LFH indicate high but variable concentrations especially at close-in sites (within 10 km), with a decrease in concentration as distance increased from the smelter.

The highest mercury level in berries (0.05µg/g) occurred at site 10 (3.2 km N.E.) in 1980. In comparison Hg levels at other sites were consistent with background levels ranging from 0.02 µg/g to 0.03µg/g. Washing the berries did not reduce Hg concentrations. The data suggest that mercury does not accumulate in blueberry fruit. In any case Hg levels did not exceed 0.05 µg/g, which is the maximum acceptable dietary concentration published by the Food and Nutrition Board, National Research Council of Canada and cited by Underwood (1973).

Mercury levels were higher in leaves, stems and roots than in the berries. Concentrations were elevated at sites within 5 km of the smelter and followed a consistent trend of decreasing levels with distance. For example Hg in leaves at site 9 (S.E. quadrant) were up to 4 times higher than the background level (site 4) in 1980 and 7 times higher than background in 1981. On the other hand, levels in stems were 14 times and 30 times higher than background in 1980 and

1981 respectively. However, concentrations decreased substantially beyond the 15 km radius. It is not known if accumulated mercury levels in the above ground parts of blueberry plants would be harmful to wildlife which use the plants for browse. To determine the possible effects a detailed study would have to be undertaken.

Highest concentrations of mercury were found in the surface organic layer of the soil (LFH); the elevated levels were a product of the long term deposition of smelter emissions. The data also show a clear trend of decreasing levels with distance from the smelter (Table 1). For example in 1980 Hg levels at site 9 were 8.54 µg/g, compared with 1.05 µg/g at site 3, and 0.37 µg/g at site 4.

Even though the LFH layer functions as the medium from which the plant obtain nutrients, no data are available to demonstrate whether mercury found in the above ground portions of the plants was absorbed by the roots. It appears that both processes of uptake, root absorption as well as direct foliar absorption of emissions may have been occurring, but the proportional contribution of each to the net accumulation was beyond the scope of this study.

The relationship between distance and 1980 and 1981 mercury concentrations in leaves, stems, roots and LFH are shown in Figures 2-5. The graphs demonstrate the exponential decline in Hg levels with distance from the smelter. The distribution pattern clearly implicates the smelter plume as the source of the mercury.

Of the many factors affecting plume dispersion, wind direction exerts the greatest influence followed by emissions, wind speed and topography (Phillips et al 1983). The wind direction in the Flin Flon area from May to August, in 1980 and 1981 had relatively strong west and northwest components with a high frequency of calm conditions (Table 3). Thus, deposition was expected to follow a directional gradient with highest levels to the east and southeast quadrant. It was for that reason that more sites were located at various distances within the southeast quadrant. Data from those sites demonstrated an exponential correlation with distance, wherein concentrations decreased most rapidly within the first 10 to 15 kilometres. Beyond 15 kilometres the levels decreased more gradually to background. As indicated previously, the existence of that relationship implicates the smelter as the source of the mercury in the Flin Flon environment.

The mercury concentration in blueberry plant components and LFH soils were generally high and of the same order of magnitude at close-in-sites (2 to 5 km) irrespective of direction. However, the relationship with distance in other directions was not studied so it is not known if that was a phenomenon only associated with close-in-sites.

2. Lead Analysis

Lead results are tabulated in Table 2 and shown graphically in Figures 6-11. The overall trends in the data are similar to those

respecting mercury. The data shows consistent patterns of elevated Pb levels close to the smelter and marked decreases with distance.

The lead levels were lowest in the berries, compared with other plant parts and washing usually reduced levels in the fruit (Table 2). For example, the highest levels found in leaves in 1980 and 1981 occurred at site 1 (S.E. sector) with levels of 1.57 and 1.18 µg/g respectively. Washing the berries resulted in a reduction of Pb concentration to 1.35 µg/g and 0.54µg/g respectively. This indicates that some lead was adhering to the berries as a surface deposit. However, even after washing, levels still exceeded the background levels found at site 4 (S.E. sector; 38.9 km from the smelter).

The average level of lead in berries (Canadian data) is 0.05 µg/g (Nutrition Foundation, 1982) which is exceeded by lead-in-blueberry data from all sites including background in the Flin Flon area. At sites within 5 km of the HBM&S smelter, the lead concentration is much higher, e.g. 20 to 30 times the Canadian average. The previous Canadian Guideline for lead in fresh fruit was 7 µg/g a figure which is presently under review in light of the tolerable daily intake of 430 µg per day suggested by the Joint Food and World Health Organization, Expert Committee on Food Additives (FAO/WHO 1972). It is not known if consumption of blueberries with 1.5 µg/g lead would be judged harmful to human health since the lead levels in the average

daily diet must be taken into account. These data have been forwarded to the Food Directorate of Health and Welfare Canada for an assessment based on dietary intake of lead for the average Canadian.

Among the other plant parts, lead was highest in the stems followed by the roots and finally the leaves. This suggests that the woody stem tissues were the focus for accumulation of lead but it is unclear whether it entered the plant through the roots or the leaves. If it was from the roots, then it was absorbed from lead in the soil but if from the leaves, direct absorption of the heavy metal emission through the leaf surface was operative. It is feasible to assume that both processes may have been occurring simultaneously.

It is not known if the lead levels in leaves and stems would be harmful to an animal eating them as browse. In the first place, it would depend on the total daily intake of lead in all browse eaten. Furthermore, it is not known what proportion of the daily or monthly diet would be made up of blueberry browse, or what the lead levels were in other dietary components. Therefore, a toxicological assessment would require an independent detailed study.

Highest levels of lead were found in the surface organic layer of the soil (LFH). Concentrations were up to 10 times higher than the background level of 120.0 µg/g at 38.9 km from the smelter. These elevated levels reflect the long term deposition of smelter emissions, which have accumulated since the smelter began operation.

Figures 6 to 11 show the distribution of lead in berries, leaves, stems, roots and the LFH soil layer. Within 5 km of the smelter, there was no apparent correlation between plume direction and lead in plant parts or LFH. Since the sites were selected to study deposition along the dominant plume direction, that is the southeast transect, there were no data to define the existence of directional gradients beyond the inner 5 km zone.

Data presented in Figures 6 to 11 clearly show the exponential relationship between lead concentrations and distance from the smelter. The pattern can be described as one of rapidly decreasing levels of lead with distance within 10 to 15 kilometres of the smelter. Beyond 15 km, the levels continue to decline to background but the rate of decline becomes progressively more gradual. That pattern clearly implicates the smelter as the source of the lead in blueberries and soil.

IV CONCLUSIONS

Mercury and lead concentrations in blueberry plant components were in excess of background levels at sites within 19.6 km of the smelter.

Mercury and lead levels were correlated with distance from the Hudson Bay Mining and smelting stack according to an exponential relationship. The smelter emissions were implicated as the source of the metal bearing deposition.

Mercury levels in berries did not exceed the maximum acceptable dietary concentration of 0.05 µg/g, published by the National Research Council. Further studies would be needed to determine possible effects on wildlife which eat blueberry browse in the area.

Highest deposition of metals occurred in the LFH layer of soil which reflects the long term accumulation of smelter emissions in the area.

Overall, the data illustrate that site specific monitoring of vegetation and soil is an effective means by which patterns of deposition from an emission source such as the HBMS smelter at Flin Flon can be determined.

TABLE 1: Mercury Concentration (µg/g) in Blueberry Plant Components and LFH, Flin Flon, 1980 & 1981.

Dispersion Sector	Distance* (km)	Site No.	Unwashed Berries**		Washed Berries**		Leaves		Stems		Roots		LFH	
			1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
[redacted]	2.0	11	0.03	0.03	<0.04	<0.03	0.21	0.21	0.15	0.16	0.08	0.48	7.80	17.80
	4.6	8	0.03	0.02	<0.04	<0.02	0.20	0.34	0.18	0.47	0.06	0.46	4.33	4.38
[redacted]	3.2	10	0.04	0.02	<0.04	<0.02	0.30	0.12	0.24	0.10	0.20	0.07	5.36	6.45
[redacted]	3.7	9	0.03	0.02	<0.03	<0.02	0.29	0.28	0.55	0.67	0.20	0.08	8.54	22.00
	5.1	1	0.03	0.02	<0.03	<0.02	0.28	0.15	0.44	0.34	0.04	0.03	7.64	10.20
	8.3	2	0.03	0.03	<0.04	<0.03	0.20	0.18	0.20	0.21	0.04	0.04	2.06	12.40
	15.5	3	0.03	0.02	<0.04	<0.02	0.12	0.11	0.11	0.05	0.04	0.03	1.05	3.21
	38.9	4	0.03	0.02	<0.04	<0.02	0.06	0.04	0.04	0.02	<0.02	0.03	0.37	0.43
[redacted]	2.5	7	0.04	0.02	<0.04	<0.02	0.33	0.57	1.18	5.16	0.07	0.03	10.00	17.80
	5.8	5	0.03	0.02	<0.04	<0.03	0.22	0.13	0.22	0.12	0.04	0.09	24.00	11.70
	19.6	6	0.03	0.02	<0.04	<0.02	0.07	0.04	0.09	0.07	0.04	0.05	1.36	1.43

* Distance from [redacted] complex

** Wet Weight Value - adjusted to a 70% water content.

TABLE 2: Lead Concentration (µg/g) in Blueberry Plant Components and LFH, Flin Flon, 1980 & 1981.

Dispersion Sector	Distance* (km)	Site No.	Unwashed Berries**		Washed Berries**		Leaves		Stems		Roots		LFH	
			1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
N-NE	2.0	11	1.02	2.31	0.69	1.29	12.0	28.0	32.0	60.0	10.0	3.2	1100.0	1600.0
	4.6	8	1.47	1.36	0.77	1.23	11.0	17.0	30.0	39.0	32.0	51.0	620.0	500.0
NE-E	3.2	10	1.31	1.48	0.49	2.00	20.0	-	59.0	36.0	23.0	74.0	940.0	770.0
E-SE	3.7	9	1.50	0.72	1.50	0.71	21.0	12.0	220.0	55.0	29.0	17.0	1500.0	950.0
	5.1	1	1.57	1.18	1.35	0.54	31.0	12.0	110.0	31.0	55.0	100.0	720.0	570.0
	8.9	2	0.63	0.72	0.58	0.74	20.0	12.0	85.0	44.0	16.0	30.0	430.0	560.0
	15.5	3	0.60	0.63	0.54	0.69	8.4	8.7	24.0	26.0	19.0	8.8	220.0	200.0
	38.9	4	0.29	0.48	0.19	0.57	5.9	2.9	12.0	6.1	4.7	2.5	120.0	51.0
SE-S	2.5	7	0.81	0.70	0.66	0.72	23.0	18.0	56.0	200.0	44.0	40.0	1200.0	910.0
	5.8	5	0.66	0.57	1.36	0.62	25.0	16.0	110.0	61.0	9.4	7.3	1600.0	1400.0
	19.6	6	0.51	0.63	0.52	0.57	12.0	15.0	68.0	45.0	43.0	32.0	470.0	630.0

* Distance from HBMS complex

** Wet Weight - adjusted to 70% water content.

Table 3: Percentage Frequencies of Wind Direction in the Flin Flon Area, May-August, 1980-1981

Wind	1980					1981				
Direction	May	June	July	August	Average	May	June	July	August	Average
North	20.9	13.7	8.6	12.0	13.8	18.4	10.3	7.8	9.3	11.5
Northeast	20.8	12.0	2.8	9.3	11.2	14.3	14.3	8.1	6.3	10.8
East	5.7	7.0	2.2	3.1	4.5	5.7	7.1	3.8	4.4	5.3
Southeast	6.5	13.3	7.4	11.6	9.7	9.4	16.9	12.6	10.6	12.4
South	9.2	12.6	11.2	13.2	11.6	16.0	14.2	13.4	18.0	15.5
Southwest	3.1	8.5	15.7	6.2	8.4	4.6	3.2	13.0	5.5	6.6
West	6.1	10.5	17.2	11.4	11.3	1.7	7.2	11.5	3.9	6.1
Northwest	12.6	8.1	12.0	11.4	11.0	3.8	13.9	12.3	11.7	10.4
Calm	15.1	14.3	22.9	21.9	18.6	26.1	12.9	17.5	30.2	21.7

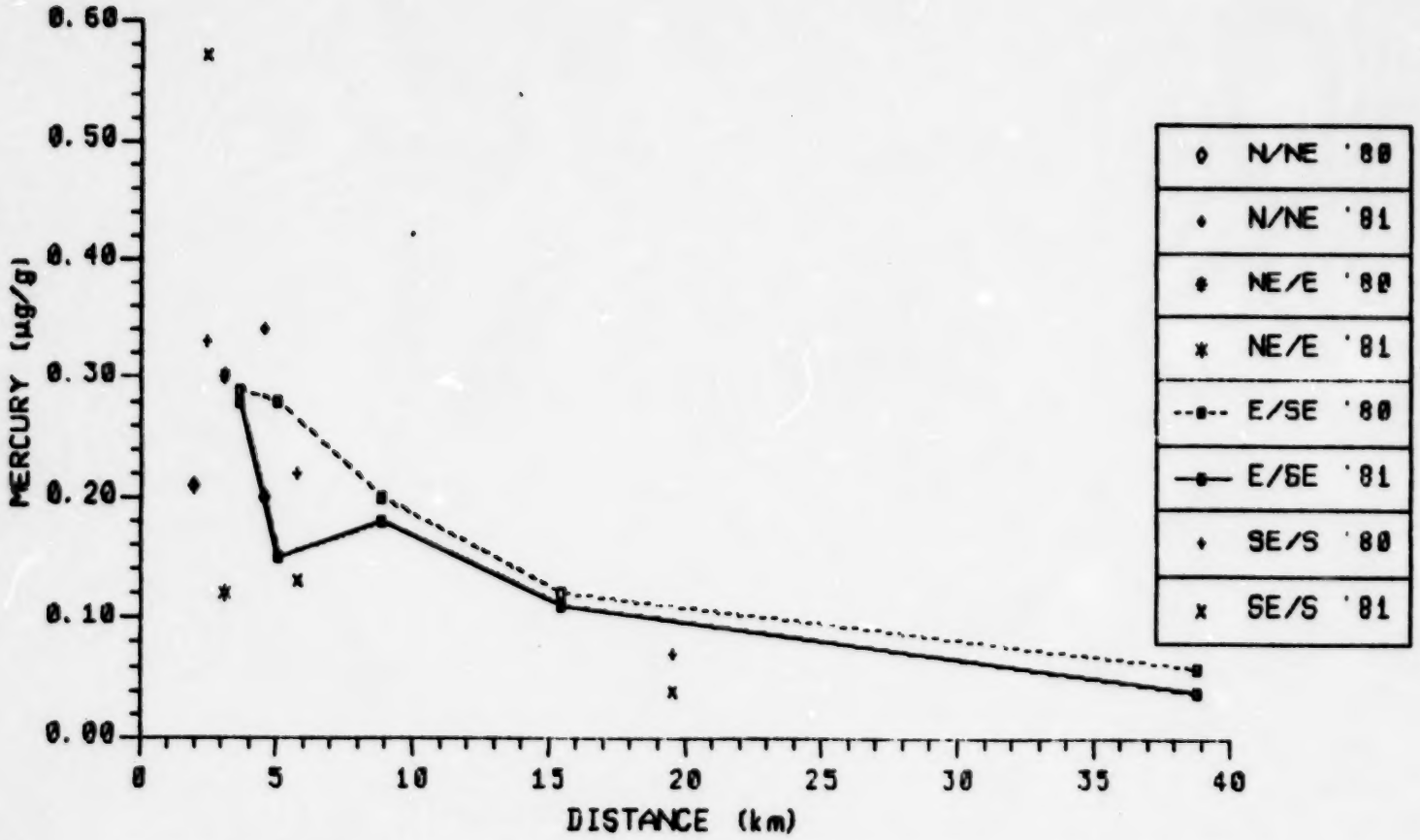


FIGURE 2: MERCURY IN BLUEBERRY LEAVES, FLIN FLON, 1980 AND 1981.

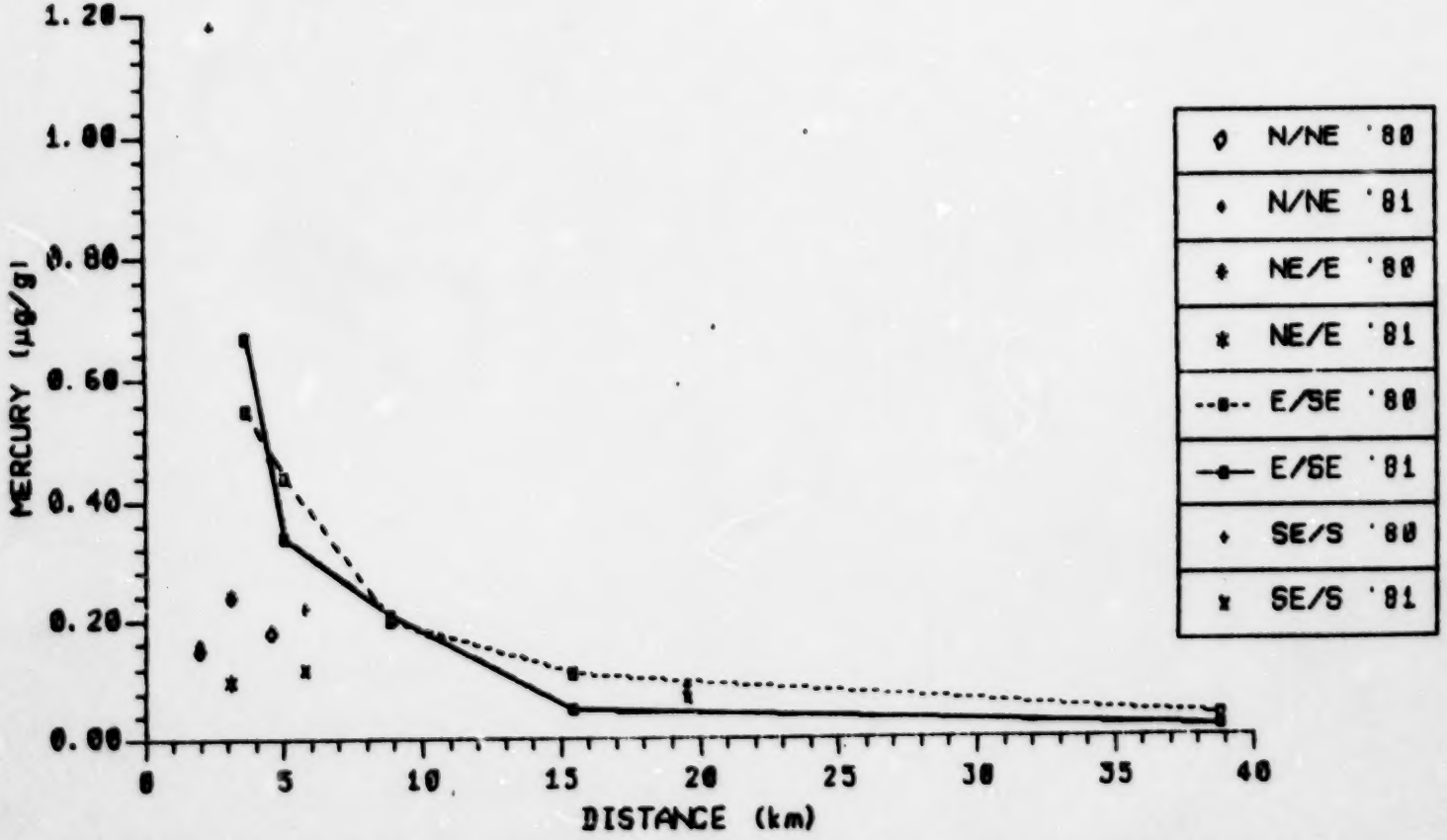


FIGURE 3: MERCURY IN BLUEBERRY STEMS. FLIN FLON. 1980 AND 1981.

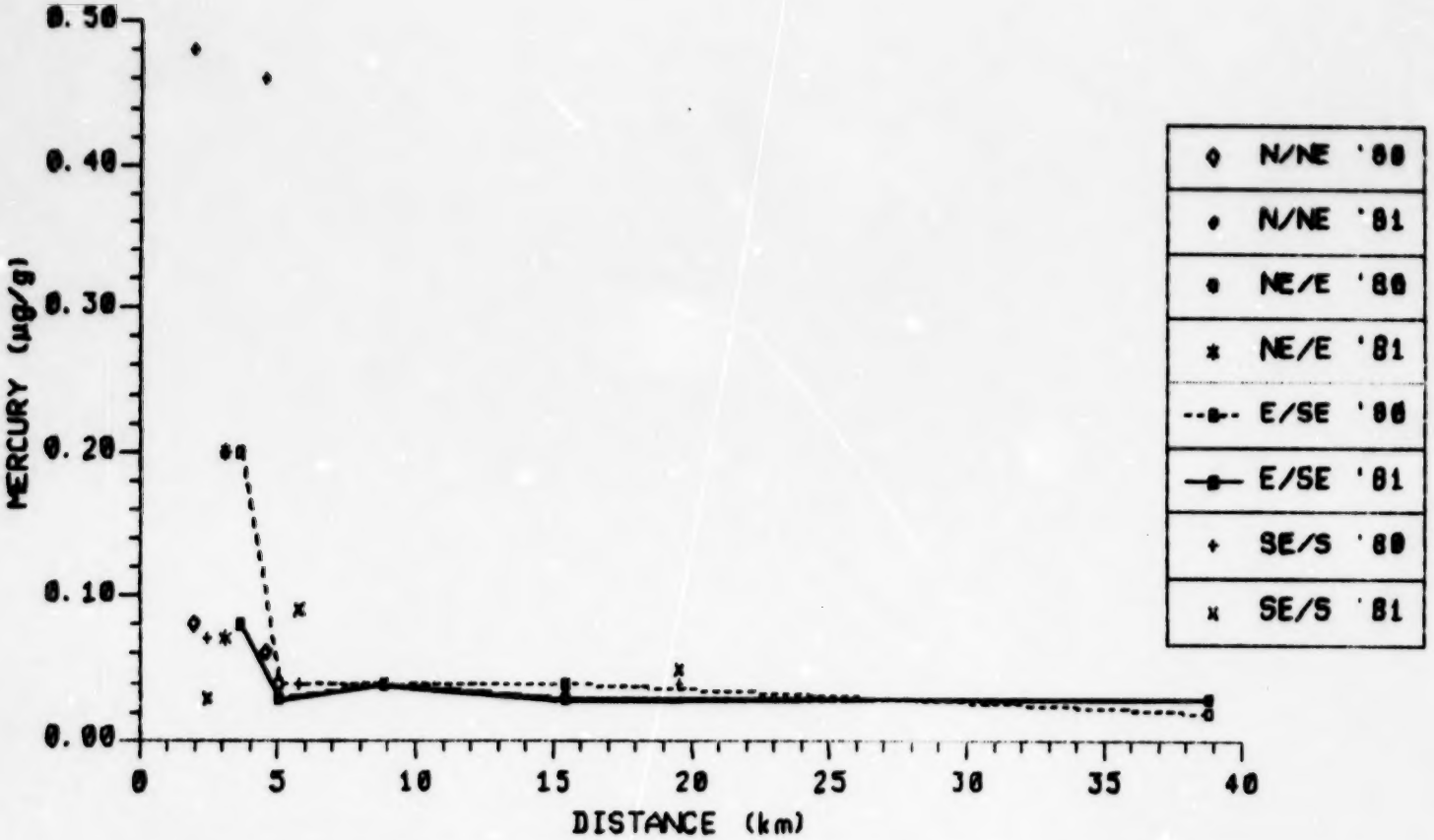


FIGURE 4: MERCURY IN BLUEBERRY ROOTS, FLIN FLON, 1980 AND 1981.

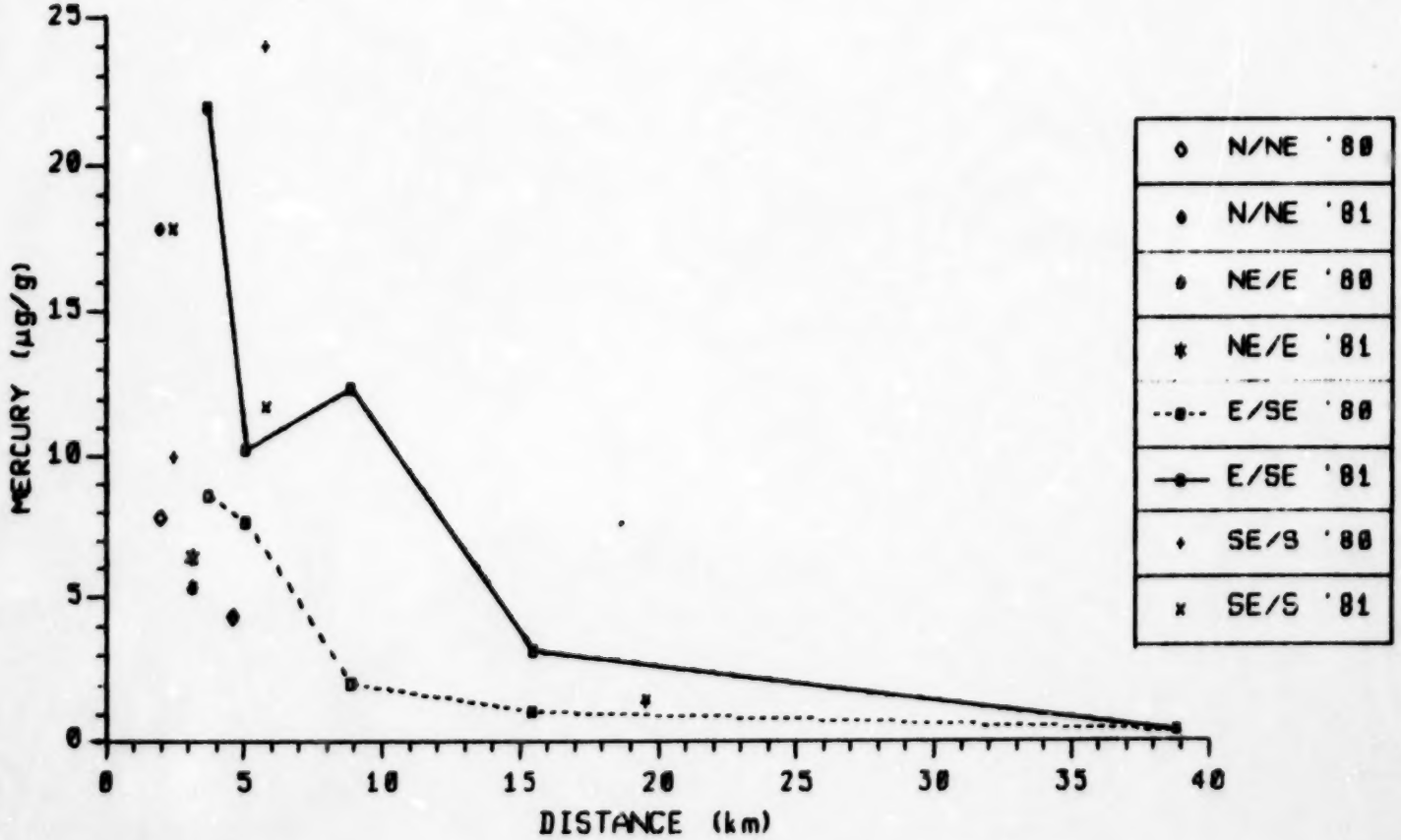


FIGURE 5: MERCURY IN LFH SOIL, FLIN FLON, 1980 AND 1981.

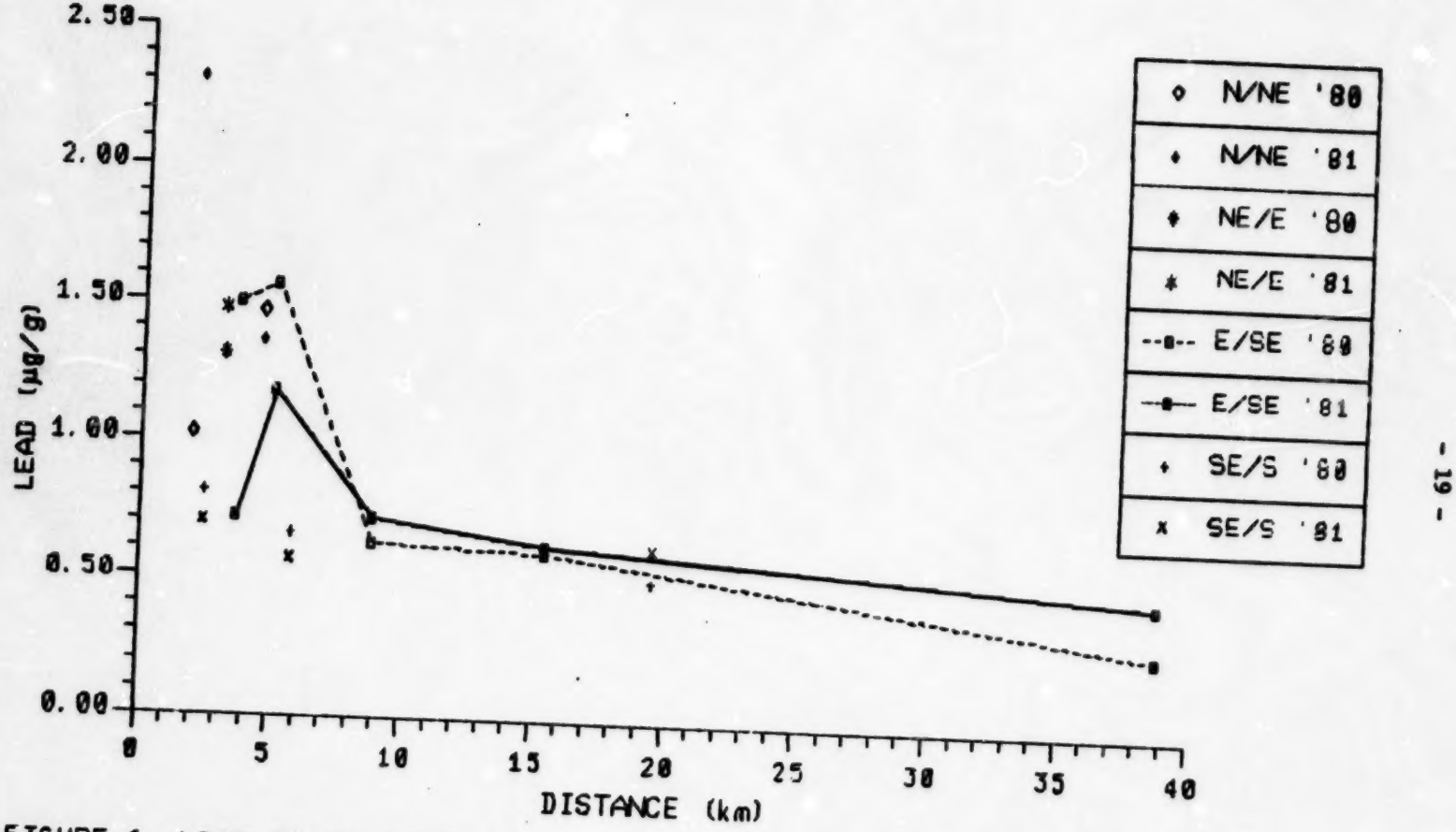


FIGURE 6: LEAD IN BLUEBERRY FRUIT (UNWASHED), FLIN FLON, 1980 AND 1981.

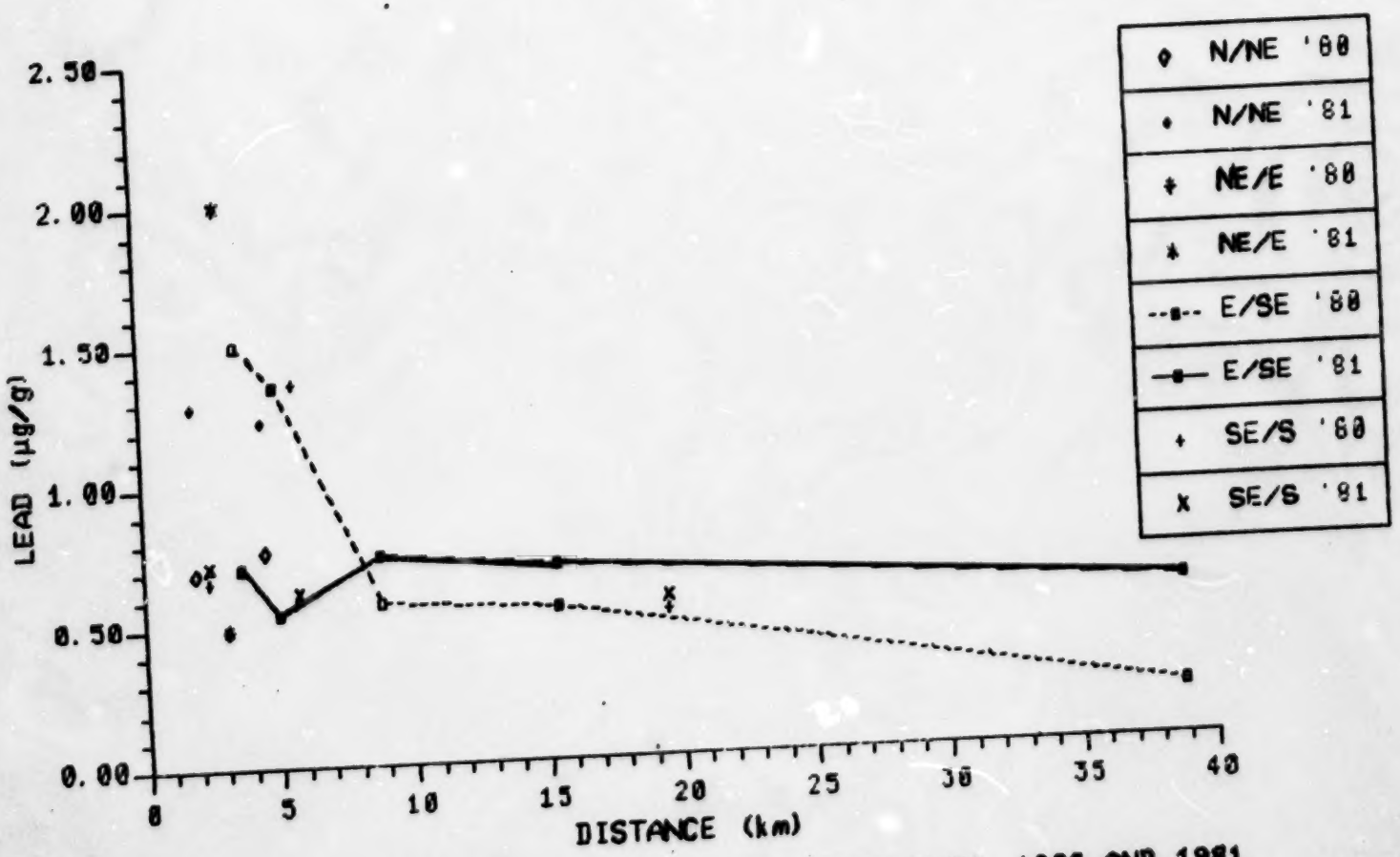


FIGURE 7: LEAD IN BLUEBERRY FRUIT (WASHED), FLIN FLON, 1980 AND 1981.

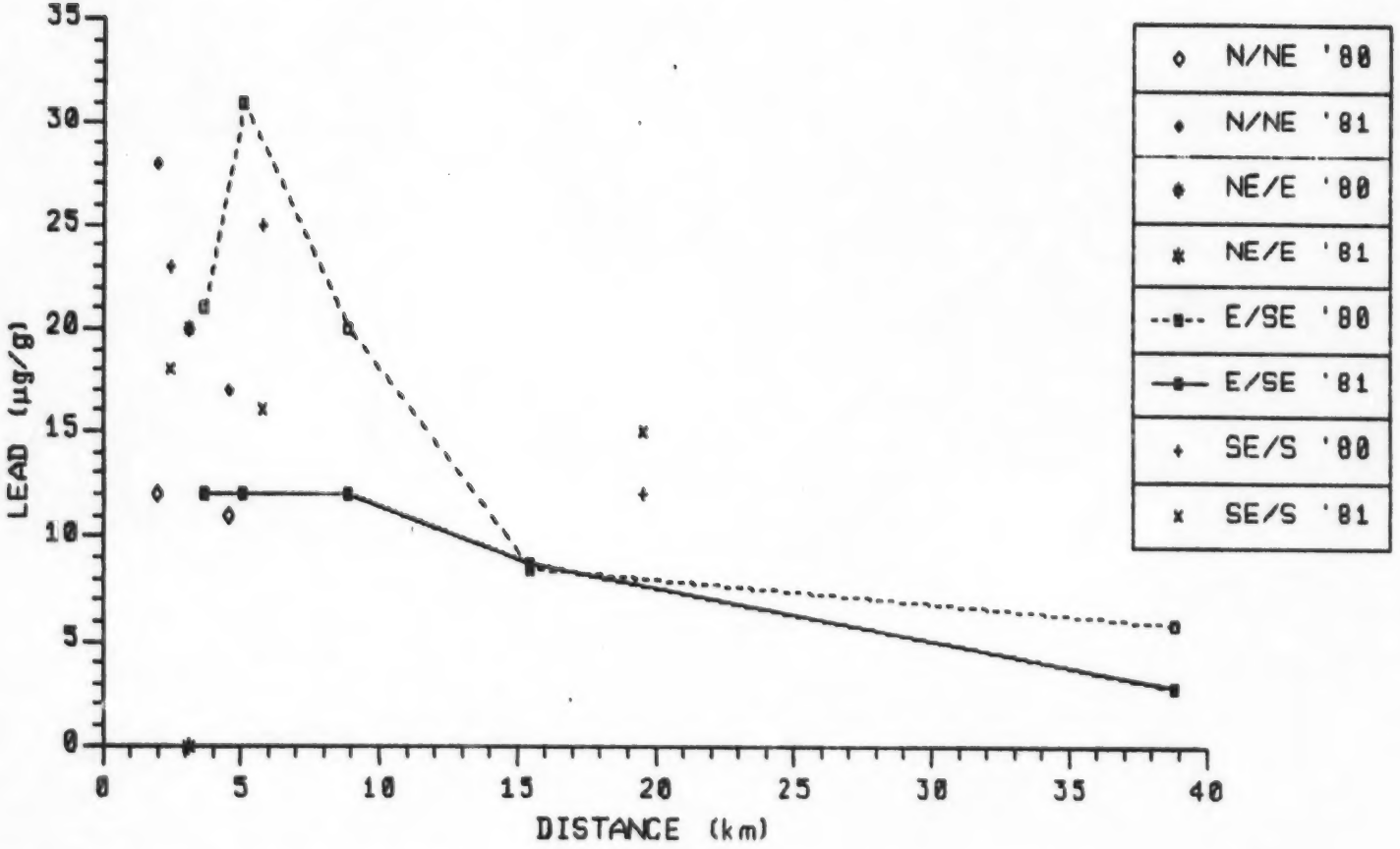


FIGURE 8: LEAD IN BLUEBERRY LEAVES, FLIN FLON, 1980 AND 1981.

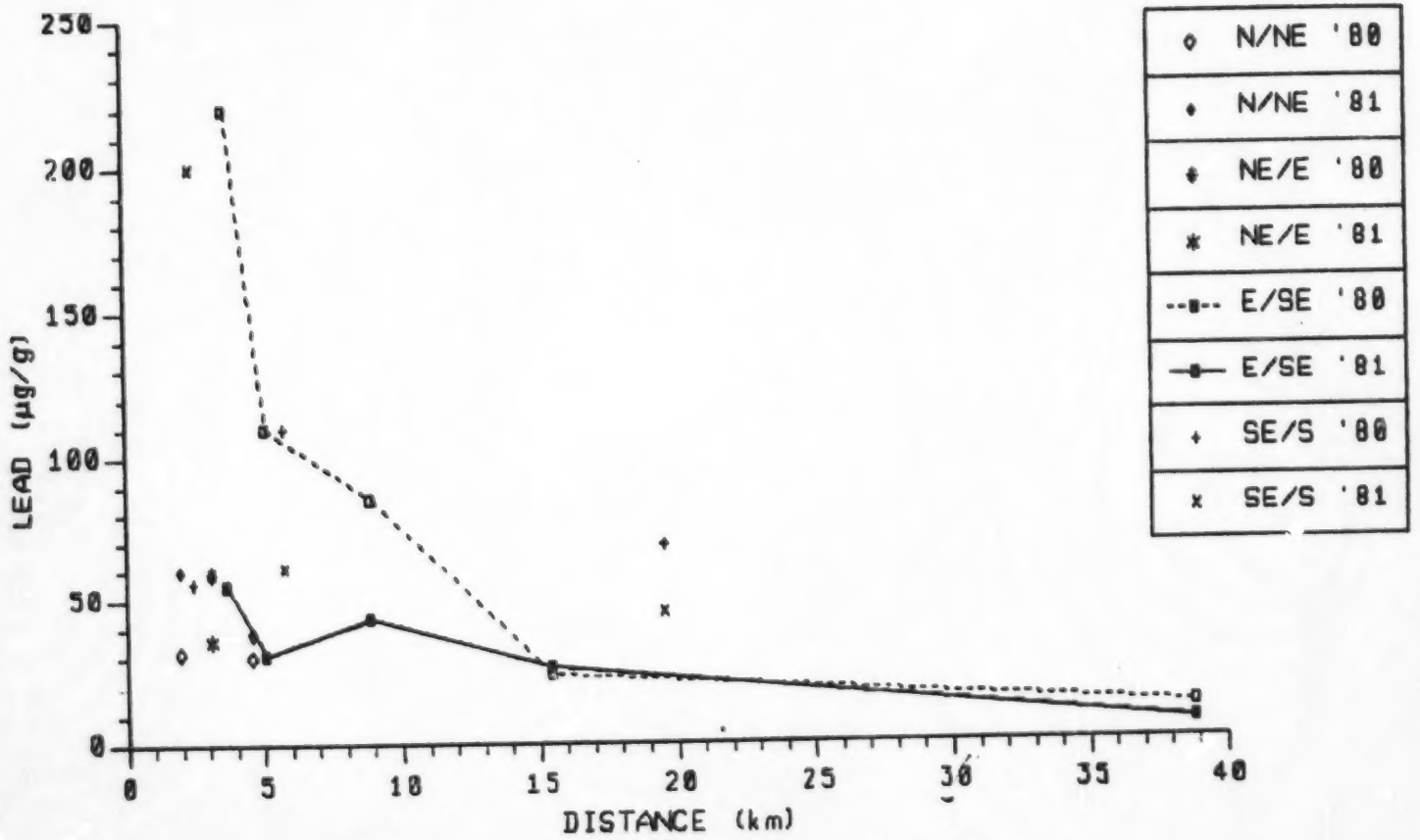


FIGURE 9: LEAD IN BLUEBERRY STEMS, FL IN FLON, 1980 AND 1981.

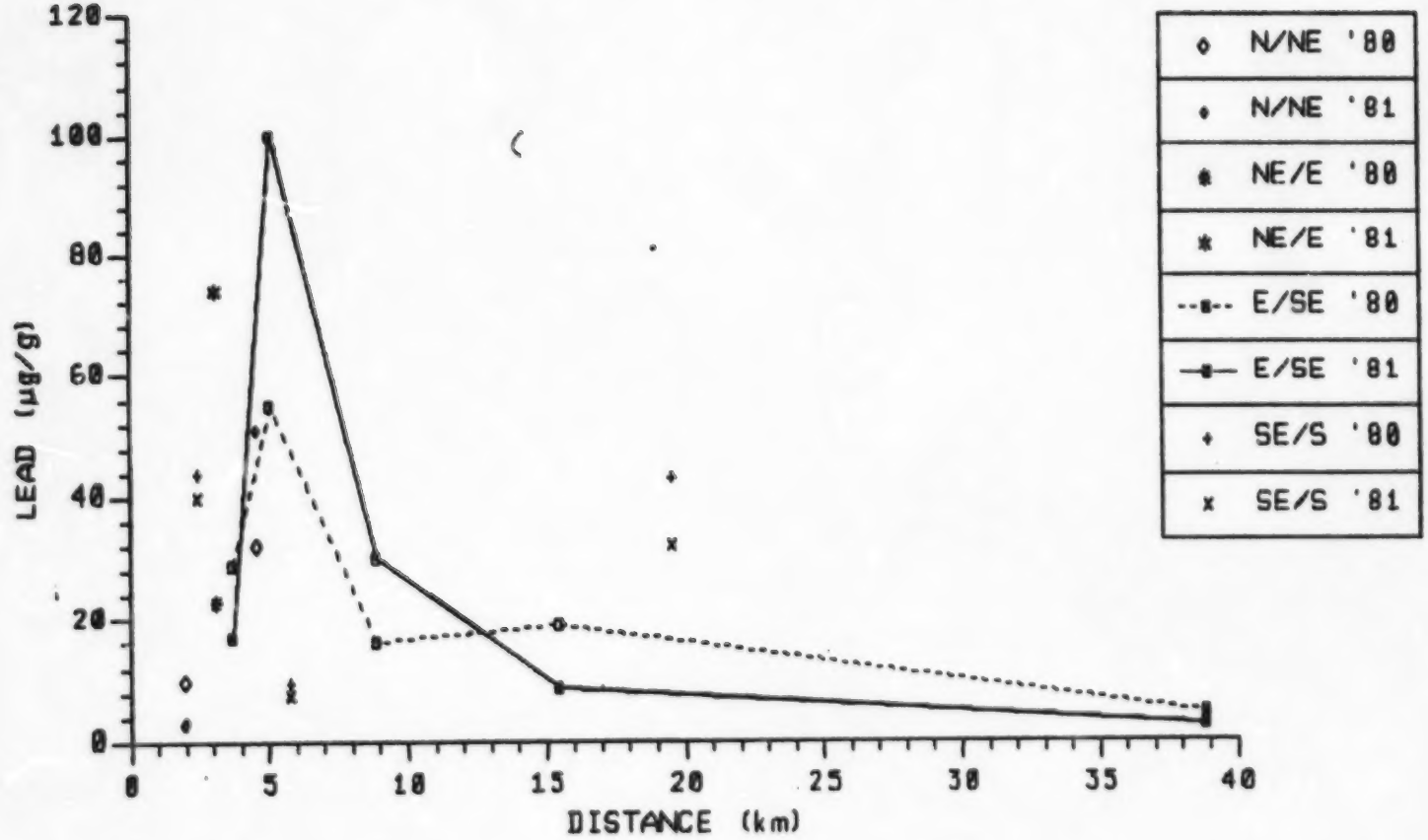


FIGURE 10: LEAD IN BLUEBERRY ROOTS. FLIN FLON. 1980 AND 1981.

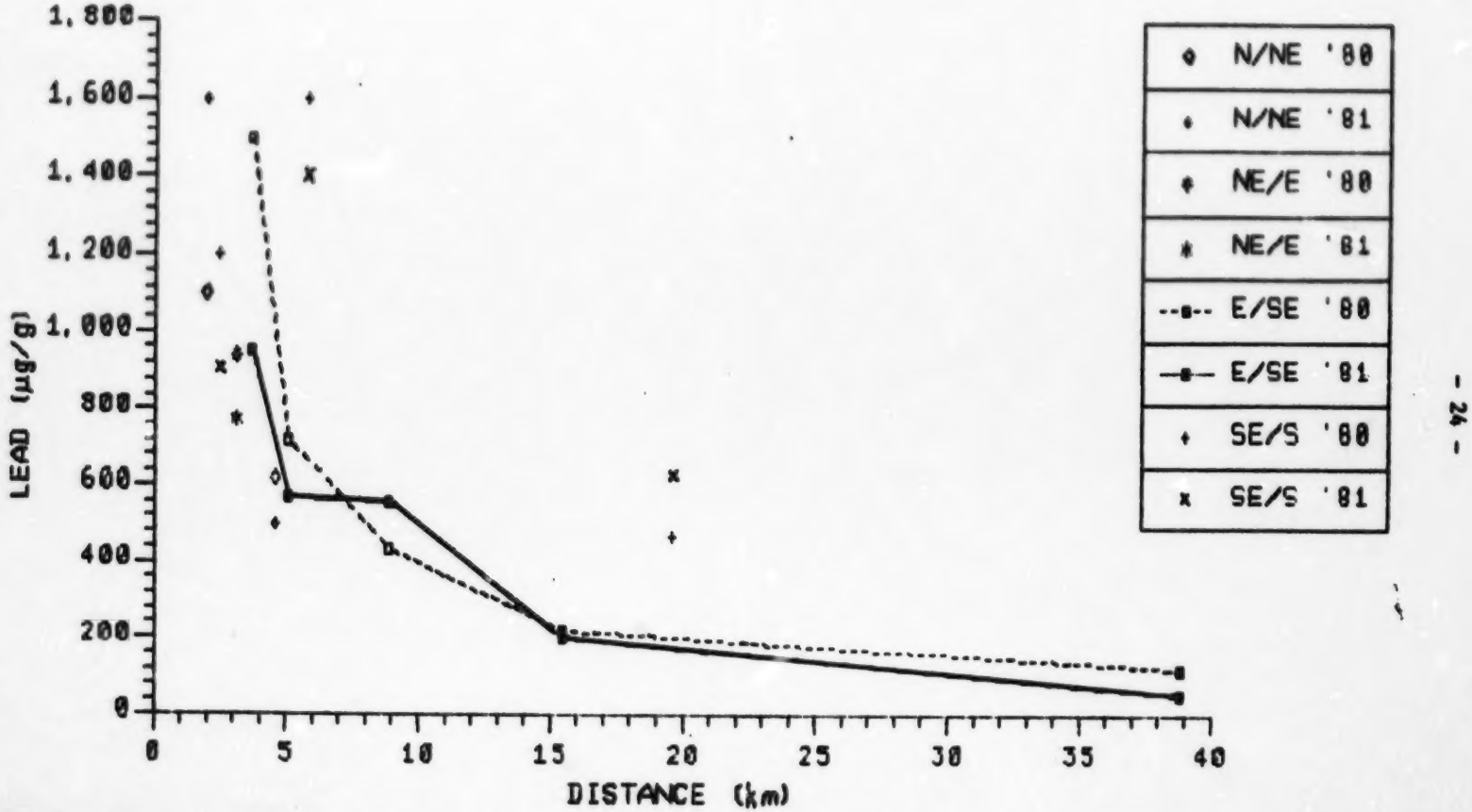


FIGURE 11: LEAD IN LFH SOIL, FLIN FLON, 1980 AND 1981.

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APPENDICES

Appendix A-1: Mercury Concentrations (μg/g) in Unwashed/Washed Blueberries, Dry Weight Values, Flin Flon, 1980 and 1981.

Dispersion Sector	Distance* (km)	Site No.	Unwashed Berries 1980	Unwashed Berries 1981	Washed Berries 1980	Washed Berries 1981
N-NE	2.0	11	0.10	0.09	<0.02	<0.09
	4.6	8	0.11	0.06	<0.03	<0.07
NE-E	3.2	10	0.13	0.08	<0.05	<0.08
E-SE	3.7	9	0.10	0.08	<0.03	<0.08
	5.1	1	0.12	0.07	<0.02	<0.07
	8.9	2	0.12	0.10	<0.03	<0.10
	15.5	3	0.13	0.06	<0.02	<0.06
	38.9	4	0.09	0.07	<0.03	<0.07
SE-S	2.5	7	0.12	0.08	<0.04	<0.08
	5.8	5	0.11	0.09	<0.03	<0.09
	19.6	6	0.10	0.06	<0.02	<0.06

* Distance from HBM&S complex

Appendix A-2: Lead Concentrations (μg/g) in Unwashed/Washed Blueberries, Dry Weight Values, Flin Flon, 1980 and 1981.

Dispersion Sector	Distance* (km)	Site No.	Unwashed Berries 1980	Unwashed Berries 1981	Washed Berries 1980	Washed Berries 1981
N-NE	2.0	11	3.40	7.70	2.30	4.30
	4.6	8	4.90	4.50	2.60	4.10
NE-E	3.2	10	3.50	4.90	1.60	-
E-SE	3.7	9	5.00	2.40	5.00	2.40
	5.1	1	5.20	3.90	4.50	1.80
	8.9	2	2.10	2.40	1.90	2.50
	15.5	3	2.10	2.10	1.80	2.30
	38.9	4	0.94	1.60	0.61	1.90
SE-S	2.5	7	2.70	2.30	1.80	2.40
	5.8	5	2.20	1.90	2.10	2.10
	19.6	6	1.70	2.10	1.70	1.90

* Distance from HBM&S complex

POOR

QUALITY

ORIGINAL